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STUDIES FOR STUDENTS.

THE DEVELOPMENT AND GEOLOGICAL RELATIONS OF THE VERTEBRATES.

III. REPTILIA. — (*Continued.*)

THERIODONTA. — This name is applied to what must be considered as a very unstable order of the reptilia. Composed as it is of the least well understood of the reptilian forms, it may at any time fall asunder under the light of new discoveries and be seen to be composed of several well defined orders instead of being a single one. The animals making up the order were originally placed by Owen in his *Anomodontia*, in the family *Cynodontia*, but were soon taken out and placed in a separate order, the *Theriodonta*. Owen's classification was arranged on the forms from South Africa only, and it was soon found that it would not suit the forms from America and Russia. Many schemes have been proposed to accommodate all of the different groups, but none has been arranged as yet that is at all satisfactory; there seems to be a general recognition of three distinct groups, but the value of these is a matter of much dispute. Lydekker, in his catalogue of the reptiles of the British Museum, would call the *Theriodonta* a suborder of the order *Anomodontia*, while Seeley, of the same institution and on the evidence of the same material, raises many forms that Lydekker regarded as families into separate and distinct orders. A quite common opinion among palæontologists, and one that may be of the greatest service to the student, is to regard the *Theriodonta* as an order and the three separate groups as suborders — the *Pelycosauria*, the *Cynodontia*, and the *Gomphodontia*.

The first of these the *Pelycosauria*, is represented most largely in the Permian deposits of the United States, but a few isolated

specimens have been found in the same horizon in Bohemia. They were in some respects of the most primitive type; the skull retained the two post-orbital arches, the teeth were simple in structure and without tubercles or basal band; the vertebræ were deeply bi-concave and pierced for the passage of the notochord; intercentra were present, and the sacrum was formed of two or three vertebræ. Not only were they the most primitive members of their order, but they were among the earliest of the land-living vertebrates after the *Amphibia*, and it is very interesting to note among their characters certain features that clearly foreshadow the culminating point of the order, the mammalia. Such characters are the great flattening of the quadrate bone and the partial surrounding of this element by the temporal bones of the skull, and the beginning of a differentiation of the teeth into specialized regions.

Dimetrodon, from the Permian of Texas, is the best known member of the suborder. There were two post-temporal arches, and the bones of the temporal region were all separate. The eyes were very large, almost perfectly round, and placed far back in the skull. The skull itself was abruptly terminated behind, and extended forward as a strong and rather high nose. The upper jaw was slightly convex on the alveolar border, and was armed with many strong, conical teeth that curved slightly to the rear; there were about three incisors in the jaw, the posterior or outer one being much larger than the others. Behind these came a considerable interval, marked by a deep notch at the junction of the premaxillaries and the maxillaries. Posterior to this came one or two very large teeth in the position of canines, followed by a long series of small conical, slightly recurved teeth of nearly equal size. The alveolar border of the lower jaw was concave to correspond to the curve of the upper, and there were two or three large teeth corresponding in position to the canines of the upper jaw. The surface of the palate and the pterygoid bones were covered by rows of small teeth. The quadrate was much depressed, and only appeared for a very small space on the side of the skull, being nearly covered by the adjoining bones. The

lower surface of the quadrate shows two parallel notches that accommodated a double condyle on the lower jaw. This absolutely prevented any lateral movement of the jaws in mastication. Not the least peculiar thing about the animal was the enormous extension of the neural processes of the spine; these were long and slender, becoming nearly as thin as a whiplash at the upper extremity. They sometimes reached a length of nearly three feet, as much as twenty-eight times the greatest diameter of the supporting vertebra. The limbs were short and stout, but from the location of the articular surfaces it seems that the legs were permanently bent, and that the animal could not raise itself from the ground. It is probable that it dragged itself along after the manner of the crocodiles. It is difficult to say what the appearance of the animal may have been. It is pretty certain that the immensely tall spines were clothed with at least a thin covering of muscle and skin, and then there would have been simply a tall dorsal fin that extended the whole length of the body. The tail of the animal was long, and the feet were strong and provided with claws. The whole brute could not have been less than eight or nine feet long.

Clepsydrops is a much smaller genus, known from the Permian of eastern Illinois and Texas. In general features it does not differ from *Dimetrodon* as far as the skeleton is known. It did not exceed a length of two or three feet.

Naosaurus can be told from *Dimetrodon* by the fact that the spines are not only elevated far above the bodies of the vertebræ, but are supplied with cross-bars like the spars of a full-rigged ship. The spines are larger and heavier than in either of the preceding genera, and are marked with shallow grooves that indicate the position of blood vessels, showing that they were covered with a layer of muscle of some thickness. Besides its occurrence in the Permian (Wichita division) beds of Texas, this genus is known from the Permian (Gaskohle) of Bohemia. The specimens from the latter locality indicate a smaller form, about two or three feet long, while the Texas specimens belong to animals nearly or quite as large as *Dimetrodon*.

The habits of these animals are a matter of great doubt. That they were very pugnacious, is well shown by the frequent fractures in the long and slender spines, which must have suffered severely when the animal got into a fight. They were carnivorous in diet.

From the Permian rocks of Russia come some very imperfectly known forms that seem to belong to this group. These are the fragmentary remains of animals discovered for the most part in working the copper mines on the west flank of the Ural Mountains in the provinces of Kasan and Orenburg in the old government of Perm. The remains are almost entirely from the upper layers of the Permian. They did not have the greatly elongated dorsal spines of the American and Bohemian forms.

Brithopus. — This form was described by Kutorga as early as 1838 from the province of Kasan, from what he then called the Keupfersandstein, now known to be upper Permian. The specimen consists of an imperfect humerus, showing the characters of the *Pelycosauria* and the African forms.

Rhophalodon is from the same region in Russia. It is characterized by the same features of the limb bones as the former genus, but the skull is unusually short and of great vertical extent; so great, indeed, as to give to it an absurdly square outline from the side view. The teeth are much stronger and stouter than those of the American forms, and have a tendency to develop in the lateral direction, giving them a rather broad outline and an appearance very similar to that of the American *Pareiasauria*, the *Diadectidæ*.

Deuterosaurus, from the province of Orenburg, in the same part of Russia, is even more similar to the American forms than the *Rhophalodon*; the skull is almost identical in appearance with that of the genus *Dimetrodon*. It seems strange at first sight to find these closely related forms from such widely separated regions as the United States, Bohemia, and Russia; but if we reflect for a moment that despite the great specialization of the American forms in the dorsal spines, this group is the most

primitive of the land-living reptiles, we may find a reason for the widespread distribution of the group.

The *Cynodontia*. — Under this head is grouped the majority of the South African forms, all except those that by their skull structure approach very nearly to the *Mammalia*. The forms considered here are the ones placed in the families *Galesauridæ* and the *Tapinocephalidæ* by Lydekker, in the catalogue of the fossil reptiles of the British Museum, under the suborder of *Theriodonta*. The group at first glimpse seems very like the *Pelycosauria*, but there is one very important distinction. The two postorbital arches of the first group have disappeared and are replaced by a single one that is either made up of the union of the two primitive ones, or is the single one left after one of them has disappeared; in all probability the first of these cases is the true one. The teeth are of carnivorous type, recurved, and in many cases differentiated into incisors, canines, and molars.

These forms are exclusively from the Karroo formation of South Africa. The position of this formation is not definitely known. It is either Permian or Permo-Triassic. If the evidence of the vertebrate remains is to be taken, it should be placed as far up in the geological time scale as possible, for there are found in these beds remains that are very closely related to forms that are found in the Lower Cretaceous of the United States.

Galesaurus, known from the skull only, was a small, lizardlike animal; the skull was depressed, with a rather long muzzle and very large temporal vacuities. The teeth were differentiated into the incisors, canines, and cheek teeth. The cheek teeth were furnished with small lateral cusps at the base. The whole skull was nearly four inches long.

Aleurosaurus is also known only from the skull. The muzzle is long but quite high, resembling in this respect the nasal portion of *Dimetrodon*. The teeth are simple and without the lateral cusps. There is a single large tusk in the upper jaw in the position of a canine. The posterior part of the skull is abruptly truncated, as in the previous suborder.

Lycosaurus was a larger form, with a skull nearly eight inches long. The upper jaw was very convex on the alveolar border, and the lower jaw was correspondingly concave. The whole skull was much depressed.

Cynognathus. — This genus is in some respects the most nearly related of the *Cynodontia* to the *Pelycosauria*, and in others most closely to the succeeding group, the *Gomphodontia*. The general aspect of the skull is that of the *Pelycosauria*. The cranial region is abruptly terminated; the jaws are curved on the alveolar border, and the teeth are divided into the separate regions. There is, however, only a single temporal arch that is almost certainly made up of the two primitive arches combined. The teeth are cuspidate, with a single tubercle in front and another behind. These are developed on the sides of the tooth as well as on the front and rear giving the first appearance of the tubercular type of the teeth. The palate bones also present a step in advance of the reptilian form. They are extended and unite in the median line, thus forming a separate cavity for the nasal organs. This, however, does not extend very far back, ending at about the middle portion of the roof of the mouth. The occipital condyle is almost double, the two sides being greatly developed at the expense of the median portion. The whole skull of one of the best known species was about fifteen inches long. The vertebræ, pelvis, and limb bones all show the same characters as the preceding group.

Gomphodontia. — The suborder is thus described by Seeley: "The *Gomphodontia* comprises animals with a Theriodont type of dentition, in which the molar teeth are expanded transversely, and have more or less tuberculate crowns of the type shown in *Diademodon*. The superior and inferior teeth are opposed to each other, and the crowns become worn with use, as in the Ungulate and other Mammals, and as in the Iguanodont reptiles. The canine teeth of the upper jaw appear to be worn at the extremities.

"It (the skull) appears to show mammalian proportions and aspect, in the definition of the large temporal vacuities, by a

zygomatic arch, which is formed by the molar and the squamosal bones, and in the separation of those vacuities from each other by a long, narrow, parietal crest. The orbit of the eye, however, is separated from the zygomatic vacuity by a postfrontal bone, so that the structure is distinct from that which obtains in the 'mammals.'

"There are two well-defined occipital condyles at the back of the base of the skull, united to each other inferiorly in a way that is closely paralleled in some mammals. The hard palate formed by the maxillary and palatine plates terminates transversely in the middle length of the molar teeth in a way that is remarkably like the dental condition of certain Marsupial mammals.

"So far as is known, there is no fundamental difference in the skeleton to separate the *Gomphodontia* from the *Cynodontia*, which may be regarded as related in the same way as are groups of the Marsupials with similarly differing dentition."

The group *Gomphodontia*, as the author of the suborder says, does not obliterate the interval between the mammals and the reptiles, but it does close up the gap to a large extent, and we are well able to see what must have been the few final steps that led to the formation of the *Mammalia*. If the quadrate should entirely disappear and the teeth take on ever so little a difference in form, if the bones of the squamosal region should coalesce, as they have almost done already, there would be no place where we could say this is reptile and this is mammal.

The known genera of this suborder are: *Tritylodon*, *Triracho-don*, *Diademodon*, *Gomphognathus* and *Microgomphodon*.

Tritylodon was originally described as a mammal by Owen. It is known only from the imperfect upper portion of the skull. The skull was long and rather narrow; the anterior nares were joined in one external opening; there were no incisor teeth, but a large pair of canines; the molar teeth were broad and supplied with three rows of tubercles; between the canines and the molars there was a long diastema. The specimen is from the Permian of Basutu-land in South Africa. From the same region

Seeley has described the forearm and forefeet of an animal that he called *Theriodesmus* which may belong to *Tritylodon.*

From the upper Triassic of Wurtemberg, near Hohenheim, Fraas has described a single tooth that bears a very striking resemblance to the molar teeth of *Tritylodon.* This tooth he calls *Triglyphus.*

Diademodon is from the eastern part of the Cape region of South Africa; it is known from an imperfect skull showing the palate and the teeth. The characteristic part of the skeleton is the broadly tubercular teeth; they are flat or cupped on the grinding face, with the edges showing many small tubercles; the appearance is not unlike that of the pig or the human tooth.

In other characters than the teeth the genus is very similar to the *Cynodontia,* and the chief point of interest to us is the evidence of a gradual progression towards a more and more complicated style of tuberculate molars that is to culminate in the multituberculate type of the most primitive mammals.

Trirachodon.—Of this genus Seeley says: "The skull in this genus has a most remarkable mammalian aspect, in form and proportion of every part. It was four inches long, as preserved, and about two inches wide behind. The orbits are circular, placed slightly in advance of the middle length of the head. The snout appears to terminate conically, rounded above and tapering forward, with a rounded alveolar margin. Each molar crown has three transverse, conspicuous ridges, but the middle ridge is the most elevated, and rises as a distinct cusp on the external and on the internal margins."

Microgomphodon.—This genus is known from the portion of a skeleton preserved in a slab of rock from the same region as the preceding genera. The teeth are the most characteristic portion; they are much enlarged in the transverse direction, being nearly or quite as long as wide. The surface is slightly convex from before backwards, and is covered with small tubercles, that become much larger at the external and the internal edges. The form is a small one, the largest teeth having a transverse diameter of two-tenths of an inch only and an antero-posterior

of one-tenth. The ribs are of the usual broad character of the African Permian reptiles generally, and the pelvis shows the broad ischium and pubis of the *Cynodontia*.

Gomphognathus.—This is perhaps the most interesting of the South African reptiles, because of its great similarity in structure to the *mammalia*. This is most apparent in the double occipital condyles, in the length of the separated nasal cavity, in the division of the teeth into premolars and molars, as well as into the major divisions of the dentition, the incisors, canines, and molars. The whole aspect of the skull is strikingly mammalian. The molar teeth have a posterior cusp or heel, and the outer edge is raised into a sharp cusp.

The geological and the geographical relations of this group are of extreme interest. They range in time only through the Permian and the Triassic. They are known only from a very limited region in South Africa, and from an even more limited region in the United States, where indeed the whole range of the fossiliferous beds is within the limits of four counties. Besides these two regions there is the case of the single tooth from the Wurtemberg region.

DINOSAURIA.—The *Dinosauria*, or the *Dinosaurs*, is the name applied to a large group of extinct animals that were confined to the Mesozoic time exclusively. When the existence of the group was first recognized by Owen, in 1839, he considered it as a well-defined order. Later discoveries have shown that under the original description there must be placed in the order animals of the most diverse character, so that it is becoming apparent that the old group must be abandoned and another, or, more correctly, several others, substituted. The very comprehensive character of the order, as usually defined, may be seen from the following characters given by Marsh, Zittel, Haeckel, and other writers on the group.

Premaxillary bones separate; upper and lower temporal arches present; no teeth on the palate; rami of the lower jaws united by cartilage only; vertebræ procœlus, opisthocœlus, or amphicœlus, sacral vertebræ united; scapula elongate; no pre-

coracoids; coracoid small; ilium greatly prolonged in front of the acetabulum; the ischia joining on the median line below; the pubis often with a strong posterior process, the post-pubic process. The form of the body and the head varies greatly in the different forms, being sometimes like that of the crocodiles and at other times like that of the birds, reptiles, or even the mammals. In the majority of the forms the hind limbs exceeded the anterior ones in size, and were used more commonly in walking; in some of the later and more specialized forms the anterior pair of limbs had lost the ambulatory functions entirely and had become wholly prehensile in character. The feet were as variously developed as the other parts of the body; in some of the forms inclining towards the ungulate type and in others developing well-formed claws. The dentition varied from the carnivorous to the herbivorous, some forms having strong recurved tusks, with serrated anterior and posterior cutting edges, and others with the jaws filled with close-set grinding teeth. The external appearance presented as many differences as the skeleton; in size they varied from that of the great herbivorous forms much larger than an elephant to the little leaping carnivorous forms no larger than a jack-rabbit. The skin of some was smooth and of others thickly covered with bony dermal plates and excrescences. Some walked erect, using the strongly developed tail as an aid in supporting the body, while others were entirely quadrupedal.

This great range of characters has led to a great number of different schemes of classification, in most of which the order *Dinosauria* has been recognized as a definite group, but it is constantly growing more difficult to keep the heterogenous assemblage together. Through all the later attempts at classification there has been a recognition of three types of structure that have been regarded as of ordinal, subordinal, or family rank by the various authors. These three divisions were regarded by Baur as distinct groups having nothing to do with each other.[1]

[1] BAUR, "Remarks on the Reptiles generally called Dinosaurs," American Naturalist, May 1891.

In his last classification of the *Dinosaurs*,[1] Marsh recognizes essentially the same group as Baur, but considers them as orders of the subclass *Dinosauria*. These three groups are called *Theropoda*, *Sauropoda*, and *Predentata;* the same groups were called by Baur *Megalosauria*, *Cetiosauria*, and *Iguanodontia*.

It is without the scope of the present article to discuss the intricate taxonomy of this group, and it will perhaps suffice to recognize the three distinct groups and to know that the tendency at the present is to consider the *Dinosauria* as an unnatural order and to speak of the *Dinosaurs* as a very loosely connected group made up of several distinct and well-defined groups.

THEROPODA (*Megalosauria*). — Brain case incompletely ossified in front; no ossified alisphenoid; an epipterygoid (columella); premaxillaries not excluding maxillaries from the nasal opening; jugal connected with the alveolar border of the maxillaries on the same plane; quadrato-jugal free from the maxillary; quadrate directly backwards; mandible without predentary bone; dentary without coronoid process; sacral vertebræ with the ribs joined intervertebrally; diapophyses of the vertebræ without connection with the ribs, but reaching out to and joining the ilium; pubes directed forward and strongly united at the distal end; limbs with the bones frequently hollow; posterior limbs much the largest; feet terminated by claws that are prehensile in the fore foot; locomotion mainly bipedal and digitigrade.

Anchisaurus, the oldest one of this group, as well as the oldest known *Dinosaur*, is from the Triassic Red Sandstone of the Connecticut Valley. A nearly perfect skeleton was obtained from these rocks in the vicinity of Manchester, Conn., in 1884. Previous to this time there had been fragments of skeletons obtained from the Triassic rocks of Pennsylvania and Prince Edward's Island, in Canada, as well as from the same deposits in the Connecticut Valley that in all probability belong to the same genus.

[1] "The Dinosaurs of North America," 16th Ann. Rept. of the Director of the U. S. G. S., Pt. I.

The skull was very birdlike in general outline; both the upper and lower jaws were full of small, sharp teeth that inclined toward the anterior ends of the jaws, and were not differentiated into molar and incisor regions (this feature occurs only in the most specialized of the reptilia); the fore limbs were much smaller than the hind limbs, but were quite large in comparison with those of the more specialized forms of later time, and perhaps took a large part in walking, although the hind limbs undoubtedly were the most largely used; all the bones of the limbs were hollow, and had very thin and solid walls, as in the birds; the fore foot had five digits, only four of which were functional; the hind limb had four toes on the foot, the fifth being a mere rudiment and the first much smaller than the others, so that the track would have been that of a three-toed animal. It is altogether probable that many, if not all, of the so-called bird tracks of the Connecticut Valley sandstone were made by these animals. One species had a length of nearly six feet, while another was much smaller, no larger than a "small fox."

Thecodontosaurus is one of the few European Triassic *Dinosaurs* that are known. It is from the Rhaetic of Bristol in England. The form is known from teeth and from portions of the skeleton; the teeth are of the typical carnivorous type, and are serrated on the anterior and the posterior borders.

Zanclodon (*Plateosaurus*) is from the Trias of many parts of Germany. The teeth are curved backward as in the preceding genus, and are serrated on the anterior and the posterior edges; the vertebræ are deeply bi-concave, and are very much longer and smaller in the cervical than the dorsal region; the limbs were short and strong and the jaws were long and curved. Only a part of the skeleton is known, although several specimens have been discovered; altogether there are about sixty vertebræ preserved in series, and these have a length of nine feet; the form is remarkable in being one of the few *Dinosaurs* that have bi-concave vertebræ.

Epicampodon is a form from the Trias of the East Indies,

Panchet group. It is known only from a few teeth having the same character as those of the previously described forms.

Massospondylus is the name given to certain remains from the Trias of South Africa, Karroo formation, and East India, Panchet group, that are known from a few teeth of the usual recurved type and some deeply bi-concave vertebræ.

Arctosaurus is from the northern part of North America, and is known only from a single vertebra.

Compsognathus from the upper Triassic of Bavaria, Lithographic Slates of Kelheim, was very similar in many respects to *Hallopus* of the Jurassic; the hind limbs were much smaller than the fore limbs, and the lower part of the leg showed the same adaptation to a leaping form of progression. The bones were all hollow and very compact in structure; the cervical vertebræ were numerous, forming a long neck, to which the head was joined at right angles. The astragalus was very closely joined to the end of the tibia, much as in the birds. Many authors have seen in this form the direct ancestors of the birds, but there are still wanting certain links to join the two forms together.

This closes the list of the well-known Triassic *Dinosaurs*. It will be noticed that they are all of the carnivorous type, though indications of a larger form of the herbivorous type are mentioned by Marsh. This author says of the distribution of the Triassic *Dinosaurs:* "It is a remarkable fact that the seven skeletons of Triassic *Dinosaurs*, now known from the eastern part of this continent, are all carnivorous forms and of small size. There is abundant evidence from large footprints that large herbivorous *Dinosaurs* lived here at the same time, but no bones nor teeth have yet been found. In the western part of the continent a few fragments of a large *Dinosaur* have been found in strata of supposed Triassic age, but with this possible exception osseous remains of these remains appear to be wanting in this horizon." Footprints "have been discovered in the Triassic sandstones of New Mexico. A few bones of a large *Dinosaur* were found by Professor Newberry in strata apparently of this age in southern

Utah. These remains were named by Professor Cope *Dystrophæus.*"

Hallopus, from the Jurassic of Colorado, is remarkable for its development as a leaping form; the femur is much shorter than the fore part of the leg and the metatarsals are greatly elongated, as in the jumping rodents. The whole form was not much larger than a rabbit.

Cœlurus, from the upper Jurassic of Wyoming, was much larger than the preceding genera, being several feet in length. It was of the same jumping type, the fore feet being much the larger. The skull is very imperfectly known. The most remarkable thing about the skeleton is the thinness of the bones and the great cavities that exist in all of them, the ribs even being hollow. The limb bones, the vertebræ, the bones of the pelvis and of the pectoral girdle, are all excavated by large air cavities that must have rendered the skeleton very light. The dentition was of the same carnivorous type as the former genera.

Ceratosaurus, from the upper Jurassic of Colorado, is one of the largest of the *Theropoda*, being about seventeen feet in length. The head was very large in proportion to the body and was quite lizardlike in many respects; there was developed on the anterior portion of the snout a strong bony process that undoubtedly supported a horn during the life of the animal. The bones of the skeleton are very light, having internal cavities such as exist in *Hallopus* and *Cœlurus*, only to a less extent; the hind limb is much larger than the fore limb, so much greater that it is possible that the fore limb was never used for other purposes than those of seizing and holding the prey of the Dinosaur. The bones of the pelvis are anchylosed together, instead of showing the sutures between the bones as in the other forms; this is an essentially birdlike feature.

Allosaurus, *Creosaurus*, and *Labrosaurus* are all from the upper Jurassic of Wyoming and Colorado. The former was one of the largest carnivorous forms of the United States, if not the largest. The total length was about twenty-one feet. Remains that have

been referred by Marsh to these genera have been taken from the Potomac Beds of Maryland.

Lælaps was one of the same type of *Dinosaurs* as those already described It is from the upper Cretaceous of New Jersey and Montana. The animal had a length of about fifteen feet.

The European forms presented scarcely less varied types than the American forms, but the bones are less well preserved and the skeletons consequently less well known. Prominent ones are *Megalosaurus* and *Streptospondylus*. The first, from the Jurassic of England and many parts of the continent, is also known from the Jurassic beds of Colorado and from the Cretaceous of the East Indies. It was one of the largest of the *Theropoda*, the femur being over a meter in length.

Aristosuchus, from the Wealden of England, is somewhat similar to *Cœlurus*, having similar cavernous vertebræ and light limb bones

Tanystrophæus, from the Muschelkalk of Bayreuth, is remarkable for the extremely elongated cervical and caudal vertebræ. They are eight or ten times as long as they are broad, and are hollow as in *Cœlurus*. The same form is known from the Triassic rocks of New Mexico.

SAUROPODA (*Cetiosauria*).— Brain case completely ossified in front; a well developed alisphenoid; no epipterygoid (columella); premaxillaries not excluding the maxillaries from the nasal opening; jugal and quadrate forming a continuation of the posterior border of the maxillary in the same plane; quadratojugal in connection with the maxillary: quadrate directed forward; mandible without predentary bone; dentary without coronoid process; sacral ribs attached to a single vertebra; neural canal much expanded in the sacrum; limb bones without medullary canal; the fore and hind limbs nearly of the same size; feet plantigrade; the termination of the toes in nails or hoofs rather than in claws.

The order is practically unknown in Triassic time, but in the

Jurassic reached a very great development, both in numbers and in diversity of forms.

Brontosaurus is from the upper Jurassic, in the vicinity of Lake Como, in Wyoming. It is the largest *Dinosaur* known, as well as the largest of the animal creation; the whole beast, from tip of snout to tip of tail, measured nearly sixty feet. The head was very small in proportion to the rest of the body, being less than the fourth cervical in size. The tail and the neck were long and quite strong. The tail was over half as long as the rest of the body; the dorsal vertebræ had a short antero-posterior extent, but were quite broad. A hole under the transverse process of each side opened into a large cavity in the body of the vertebra, probably for the purpose of reducing weight. The pectoral girdle is represented by the usual elements, but the coracoid is very much smaller than the scapula and the sternum is composed of two pieces, one on each side of the median line as in the embryos of birds. The neural canal is greatly enlarged in the sacral region; this enlargement begins even in the cervical region, so that it would have been possible to have drawn the whole of the brain down through the neural canal.

It is difficult to see how an animal that had reached the unwieldy size of the *Brontosaurus* could have supplied itself with food; the very small head and rather weak dentition would seem to render the actual task of getting a sufficient supply of food into the enormous body a very difficult one, even granting that the food was most plentiful; but if the animal was compelled to search to any extent for its supplies the work must have been an almost constant one. This is especially true because the food was entirely vegetable, and the proportion of such food necessary to support a body is much greater than the more condensed food of the carnivorous forms. The animal was in all probability semi-aquatic in its habits and lived for a good part of the time in the waters of the oceans and the lakes of the later Jurassic and the early Cretaceous time. That they suffered much from their great bulk is evident from the condition in which the skeletons are found; they are in many cases complete and undisturbed,

showing that the animal was mired down in some hole or on the uddy bank of some body of water.

Camarasaurus (*Atlantosaurus*) was very similar to the preceding, differing in the fact that the sacral and the caudal vertebræ are solid, instead of having the large vacuities that are found in the same bones of the preceding genus and in the vertebræ of the anterior region of this genus. The scapula of one specimen measured one and a half meters, and the femur nearly two. From the Upper Jurassic of Colorado.

Morosaurus, *Allosaurus*, and *Apatosaurus* are all forms that are distinguished by minor characters of the vertebræ, and limbs from the preceding genera. They are all from the same horizon as the preceding, in Wyoming and Colorado.

Cetiosaurus is from the Upper Jurassic of England; the form is so similar to that of the various American forms that Baur has suggested that all the genera from Colorado and Wyoming are possibly the same as the English one. The skeleton is only partially known, the head being missing in all the known specimens. It was nearly thirty-five feet in length, with about the same proportions of the fore and hind limbs, and the vertebræ as *Brontosaurus*.

Ornithopsis, from the Upper Jurassic of England and France is very similar to *Cetiosaurus*, but shows large vacuities in the sides of the dorsal vertebræ.

Diplodocus, from the Upper Jurassic of Colorado and Wyoming, is remarkable for the long cervical and caudal vertebræ. The vertebræ were very light and hollow, those of the sacral region especially. The chevron bones, instead of being simple, with only the single V-shaped branch, were composed of two V-shaped branches that extended forward and back, and were united at the proximal extremities. The jaws were edentulous, except at the anterior ends, and these were supplied with long, slender teeth that were constantly shed and renewed from below, a specimen with as many as seven successive teeth in various stages of development being known.

Titanosaurus is the name given to certain large vertebræ, from

the Middle Cretaceous layers of the East Indies. The same vertebræ have been found in the Cretaceous of England.

A very imperfectly known form, *Aepysaurus*, is found in the Cretaceous of France.

Imperfect remains have been described from Patagonia, *Argyrosaurus* and *Titanosaurus*, and from Madagascar *Bothriospondylus*.

Some teeth and parts of vertebræ have been discovered in the upper part of the Potomac formation of Maryland.

It will be seen that the *Sauropoda*, as far as we know them now, are for the most part confined to the continent of North America. The few forms that are found in the other parts of the world indicate the wide extension of the group, but in these there is no indication of such a degree of specialization as was attained by the North American forms. This continent seems to have been the home of the group and the seat of their greatest development.

PREDENTATA (*Iguanodonta*).— Brain case completely ossified; a well-developed alisphenoid; no epipterygoid (columella); premaxillaries, with a posterior outer process extending between the maxillaries and the nasals, excluding the maxillaries from the nasal openings; jugals fixed to a special process outside of the alveolar process of the maxillaries; posterior border of the maxillaries free, not attached to the jugal or the quadrato-jugal; quadrate directed forward; the anterior end of the mandible furnished with a distinct predentary bone; dentary with a greatly developed coronoid process; sacral vertebræ, with the ribs and the diapophyses attached, and the ribs joined to two vertebræ (intervertebrally); pubis consisting of two branches, the anterior one, ectopubis (pectineal process, prepubis) extending far forward and joined with the one of the opposite side by suture; the posterior one, the entopubis, extending far backward, and lying parallel to the ischium, is well developed in some forms, but in others rudimentary; illium much extended in front of the acetabulum, and also reaching far behind. In some forms of this suborder the fore and hind limbs were of nearly equal size,

while in others the hind limbs were nearly as large in proportion to the front limbs as in the *Theropoda;* the feet were armed, in the majority of cases, with flat claws, or hoofs. The dentition shows that the animals were herbivorous in diet, and the mouth is, in some forms, crowded full of teeth. This group did not develop the enormous size of the preceding group, but sought protection in the development of a bony armature that rendered them, in many cases, safe from the attacks of the carnivorous forms.

Stegosaurus.—The jaws were furnished with teeth in the posterior portion only, the premaxillaries being edentulous and probably covered with a horny beak that served the animal in gathering the plants which formed its food. The teeth were flattened sideways, and the crowns were serrated; the limbs, bones, and the vertebræ were solid; the fore and hind limbs were of the same size; the neural processes of the dorsal vertebræ were quite high, and supported the ribs from near the apex; the feet were plantigrade, and the toes terminated in broad, hooflike claws. The most remarkable thing about the form was the fact that there were developed in the skin of the back and sides great, broad plates of bone that possibly stood up as a median ridge along the back. All the known specimens are from the Upper Jurassic of Colorado and Wyoming.

Camptosaurus, *Laosaurus*, *Dryosaurus*, and *Nanosaurus* are all from the same horizon and the same localities as *Stegosaurus.* They resemble that form in the arrangement of the pelvis, the bones of the skull, and all the essential features of the group, but differ in many external characters. The hind limbs are much larger than the fore limbs, and seem to have monopolized the function of progression; the fore feet are very small, and could only, under peculiar circumstances, have served as organs of locomotion. There were five functional digits on the fore feet and only three on the hind foot, so that the tracks would have been the same as those of a large bird, and it is very probable that the tracks in the Triassic sandstone of the eastern part of the United States may be tracks of these or of related forms,

instead of birds, as originally supposed. The bones are all hollow, and the whole skeleton was very light. There was an almost complete absence of the dermal armor that characterized the *Stegosaurus;* the whole lightness of the skeleton is incompatible with the weight of such a covering, and it is likely that the animals sought safety in flight, where the former genus trusted to the impenetrability of its armor. The largest of the four genera, *Camptosaurus*, was about twenty feet long, and the smallest, *Nanosaurus*, was only three or four. The last genus is the lightest and the most birdlike of all the *Dinosaurs*.

Dystrophæus is the name given by Cope to the incomplete remains of a *Dinosaur* from the Triassic rocks of Utah. There is preserved only the portions of the hind limb but these show that the animal had only three functional digits on the hind foot and that it was closely related to the *Camptosaurus*.

Teeth from the Potomac formation, evidently belonging to this group have been described by Marsh and Leidy as *Priconodon* and *Paleoscincus*.

Euskelosaurus from the South African beds is too incomplete to be definitely placed anywhere, but is generally placed among these forms.

Scelidosaurus is from the lower Lias of Dorsetshire in England. It was very similar in many respects to *Stegosaurus*, having the same quadrupedal locomotion and the same solid form of the bones but the dermal armor was reduced to a single row of small ossicles down the median line of the back. The whole form was nearly twelve feet long.

Agathaumus from the Upper Cretaceous of Wyoming, is one of the most peculiar of this peculiar group of animals; with the same bodily characters of the trunk as the *Stegosaurus*, minus the dermal plates, the interest of the form centers in the enormous development of the protective armature of the skull. The bones of the posterior cranial region were developed as an enormous cape that extended back over the shoulders; around the edges of the cape there was a series of smaller bones. The frontal portion of the superior aspect of the skull was protected by the

development of three large horns, two of these, the largest, projected from the superior edges of the orbital rims, the others from the anterior part of the snout. One skull taken from the Laramie Cretaceous of Converse county Wyoming, was eight feet from the tip of the snout to the tip of the posterior edge of the skull, and weighed, with the matrix of sandstone, 3600 pounds. The teeth were set in a single row in the jaws and were provided with two roots, a rather peculiar condition in the reptiles. The teeth were transverse and presented broad grinding surfaces. The whole body was stout and elephantine in proportions; the skin was undoubtedly furnished with small dermal ossifications spread through its surface. The tail was long and heavy. The animal must have been, according to Marsh, twenty-five feet long and about ten high.

Torosaurus from the same horizon as the last was smaller, but still quite large, as one skull measured five and a half feet across the top. The most remarkable thing about this form was the great posterior development of the capelike portion of the skull. It extended much farther back than in *Agathaumus* and was perforated by two large fontanelles in the posterior part. The whole plate is much thinner than in the other form.

Claosaurus is from the same region as the preceding and bears about the same relation to those forms that *Scelidosaurus* does to *Stegosaurus*, that is, the general characters of the body are the same, but the peculiar specialization has disappeared. This animal developed the posterior limbs at the expense of the anterior ones, as organs of locomotion. Oddly enough the front feet did not assume the function of grasping organs as in the *Theropoda*, which assumed the bipedal form of locomotion, but retained the broad terminal phalanges that indicate the possession of hoofs on the front feet even after they had grown so short that they could not have reached the ground. The hind feet possessed three functional digits as in *Agathaumus*. The mid-dorsal series of vertebræ was strengthened by the presence of many long ossified tendons that extended for some distance on each side of the neural spines. The limb bones were solid.

The whole animal attained a length of about thirty feet and was probably about fifteen high when it stood erect.

Hadrosaurus is from the same region as all the forms just described and presents the peculiar feature of a flattened snout, resembling the bill of a duck, or the snout of the Australian mammal, *Ornithorhynchus*. Only the skull is well known. The anterior ends of the jaws were edentulous, and were probably covered by a horny sheath; the posterior portions were filled with a large number of teeth that were disposed in rows, and were successional in arrangement so that as fast as the old teeth were worn out new ones, developed in the sides of the jaw, came in to take their places. In one specimen Cope counted six hundred and thirty teeth on each side of the upper jaw and four hundred and six on each side of the lower jaw, making a total of two thousand and seventy-two. The animal was probably aquatic in its habits of feeding, and used the ducklike bill much as the bottom feeding aquatic birds do in gathering up the ooze and slime that contain their food. The fragments of the skeleton that are known indicate that the animal had the same relative proportions of the fore and hind limbs as *Claosaurus*.

Agathaumus, most generally, but erroneously, called *Triceratops*, *Torosaurus*, *Claosaurus*, and *Hadrosaurus* are all from the Upper Cretaceous, the Laramie, and from a very limited region in the northeastern portion of Converse county in Wyoming. A few remains of these forms have been found in near-by portions of Wyoming and Montana.

Iguanodon is the European representative of the *Predentata*. It is one of the few members of the group found outside of the United States. It was of the bipedal type, the hind feet being larger than the fore feet and the whole hind limb showing the more robust character so common in the American forms. There were three functional toes on the hind foot and three on the fore foot, but there were two, the first and the fifth, on the fore foot that are entirely lacking on the hind foot. The first digit on the fore foot was modified in a most peculiar manner into a short and strong spurlike process that stood out at right angles to

the rest of the digits. The vertebral column was strong with well developed neural processes on the dorsal vertebræ which were further strengthened by ossified tendons that aided in moving the heavy tail. The postpubis was long and extended back almost to the distal extremity of the ischium. The teeth were of the same type as the American forms, broad laterally, with serrated edges, and adapted to the trituration of vegetable food. There was no dermal armor as far as known but it is possible that there were small bony ossicles developed in the skin. The animal reached a length of thirty feet in the largest genus and about half of that in the smallest. It is known from the Wealden of England and France, the most important deposit, however, is from the same horizon in the neighborhood of Bernissart, in Belgium, from which region a large number of skeletons have been taken, the majority of them in a very perfect state of preservation.

A description of the *Dinosaurs* would not be complete without some mention of the fossil tracks in the Triassic sandstones of the eastern part of the United States. These are typically developed in the rocks of the Newark group in the valley of the Connecticut River, and are also found in these same rocks where they appear in Pennsylvania, Virginia, and North Carolina. A very large number of these impressions have been taken from the Connecticut region, and over a hundred separate species have been named from them. They are almost all three-toed forms and range from about an inch in length to over a foot. They are found associated with amphibian tracks. The course of the tracks may, in some instances, be traced for many feet or yards, and the length of stride and the character of the feet of the two sides can be clearly made out. The majority of the impressions show that the animals walked on the hind feet most of the time, only occasional traces of the front feet being found. In some cases a long groovelike track indicates where the tail of the animal was dragged through the mud. Because of the three-toed character of the tracks and the peculiar resemblance to the tracks of birds they were originally described by Hitchcock as bird tracks (*Ornithichnites*).

Translating very freely from Zittel's *Handbuch*, we have the following summary of the range and distribution of the *Dinosaurs:*

In general we may say that Europe and North America were, during the Triassic, Jurassic, and Cretaceous times, the home and the region of the greatest development of the *Dinosaurs.* From the East Indies only incomplete remains are known from the Trias and the Cretaceous, and from South Africa, only enough remains to say that there were *Dinosaurs* there. In South America and Australia the remains of these animals are, as yet, completely unknown.

Although the largest number of forms as well as the most perfectly preserved remains are known from the United States, Europe affords many specimens of all the principal groups. The American *Sauropoda* are represented in Europe by *Cetiosaurus, Ornithopsis* and an incompletely preserved Cretaceous form. The *Zanclodontidæ* parallel to some extent the *Anchisauria.* The *Megalosauria* of Europe are represented in this country by *Allosaurus, Lælaps,* and several less well-known forms. The *Ceratosauria* are unknown in the Old World, and the *Cœluria,* hollow-boned forms, are represented by *Calamospondylus* and *Aristosuchus. Tanystrophæus* belongs to both the Old and the New Worlds. The European *Compsognathus* is found in the *Hallopus.* Among the *Predentata* the *Scelidosauria* are confined to Europe while the *Stegosauria* are mostly American. *Omosaurus,* if not a synonym of *Stegosaurus,* would be a European representative of this group. The forms from the Laramie Cretaceous are all confined to the American continent.

From a geological standpoint the original distribution of the *Dinosaurs* was practically contemporaneous, though even in the Trias there were well defined areas containing differentiated forms, and this differentiation by local development was accentuated in the Jurassic and Cretaceous. Animals from the two continents frequently belong to the same families but seldom to the same genera and species.

Perhaps the most peculiar thing about these forms is the sudden and complete destruction of the whole order at the end of the Mesozoic time. The Cretaceous rocks just at the end of the period show that there was a very large number of individuals as well as species, but the earliest of the Tertiary series are as free from their remains as the most recent formation. There is no cause for this sudden extinction of a great group unless it was a climatic one, and even this is not indicated by any change in the vegetable life of the two periods.

Below is a list of the various genera of the Dinosaurs arranged to show their systematic and time relations.

	Triassic	Jurassic	Cretaceous
THEROPODA	*Anchisaurus*	*Cœlurus*	*Lœlaps*
	Zanclodon	*Ceratosaurus*	*Ornithomimus*
	Epicampodon	*Allosaurus*	*Megalosaurus*
	Massospondylus	*Labrosaurus*	
	Arctosaurus	*Creosaurus*	
	Tanystrophæus	*Megalosaurus*	
		Streptospondylus	
		Aristosuchus	
		Compsognathus	
		Hallopus	
SAUROPODA		*Brontosaurus*	
		Camarosaurus	
		Morosaurus	
		Apatosaurus	
		Cetiosaurus	
		Ornithopsis	
		Diplodocus	
		Titanosaurus	
PREDENTATA	*Dystrophæus*	*Stegosaurus*	*Agathaumus*
	Euscelosaurus	*Camptosaurus*	*Torosaurus*
		Laosaurus	*Claosaurus*
		Dryosaurus	*Hadrosaurus*
		Nanosaurus	
		Scelidosaurus	

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